Validation and Error Characterization for the Global Precipitation Measurement

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I. INTRODUCTION

The Global Precipitation Measurement (GPM) is an international research initiative led by the National Aeronautics and Space Administration (NASA) of the U.S. and the National Space Development Agency (NASDA) of Japan. The research goals of GPM are to enable improvement of weather, climate, and hydrological prediction through more frequent and accurate sampling of precipitation over the globe. The GPM space borne capacity will consist of a constellation of meteorological research and operational satellites contributed by both domestic U.S. and international partners. A critical component to the space borne constellation is the Core Satellite as a platform for a conically scanning microwave radiometer, the GPM Microwave Imager (GMI), and for two cross-track scanning radars, the Dual-frequency Precipitation Radar (DPR). In accord with the U.S./ Japan partnership, NASA will provide the GMI and the Core spacecraft and NASDA will provide the DPR and launch vehicle. A second GMI sensor will be flown aboard a NASA-launched Constellation spacecraft. In addition to space borne assets, the GPM partnership will broadly extend to domestic U.S. and international organizations for conducting global ground validation and precipitation research.

The GPM is a three-year on-orbit duration program with a five-year duration goal. The Core satellite launch is scheduled tentatively for Fall 2008. Presently, GPM is in formulation stage in which the team is developing concepts and requirements prior to design work. As a part of formulation, ground validation is developing its requirements with a top-level schedule requirement of commencing GV operations two years prior to the Core satellite launch. The rationale is that GV will benefit from a two-year head start in preparation for the Core observations. The requirements for GV are being developed in collaboration with, and vetted by, the precipitation science community.

Ground validation [1] is managed as an element within the GPM Project Formulation Office at NASA Goddard Space Flight Center in a manner similar to the spacecraft instrumentation, observatory, mission operations, and data processing elements. Ground validation is a critical mission component and is fully integrated into the overall mission requirements and concept. As such, GV is subject to mission requirements reviews, design reviews, readiness reviews, integrated mission schedules, and mission quality assurance. Inherent to this approach is recognition that GV is a unique and complex element, involving research, within the structure of the spacecraft mission.

II. GROUND VALIDATION OBJECTIVES

The goals of the ground validation effort are three-fold:

1) Error characterization of satellite retrievals,
2) Satellite algorithm improvement, and
3) Research.

A. Error Characterization of Satellite Retrievals

The first of these objectives, satellite retrieval error characterization, is the quantitative estimation of retrieval error in terms of its random and systematic components. The objective is to provide uncertainty estimates and systematic estimates concurrently with the retrievals at the GPM ground data system, the Precipitation Processing System (PPS). Error characterization also addresses error covariance, which represents the level of independence or correlation between the random sources of error. Covariance provides the structure of error, and their dependence, as functions of space, time, or some physical variable.

B. Satellite Algorithm Improvement

The second objective, algorithm improvement, recognizes the unique role of ground validation and the satellite observations. GPM satellite algorithms will operate upon radiometric brightness temperatures, dual-frequency radar reflectivities, and a combination thereof. Ground validation is able to explore these measurands, as well as precipitation estimation, at higher spatial and temporal resolution than is possible with the satellite observations. Ground validation is capable of examining, in detail, the assumptions and models upon which the algorithms are based. Toward this end, algorithm developers will provide the GV team with information on these fundamental physical assumptions and models. In addition, the developers are asked for their appraisal on which assumptions warrant GV attention.

C. Research

The third objective, research, recognizes that ground validation is accomplished only through advancing the state of precipitation research. New tools, techniques, models, and ground-based retrievals will be developed and refined in the processing of addressing the first two objectives of GV. Although the GV effort has operational objectives in terms of error characterization and algorithm improvement, the paths to these objectives are accomplished through research.

D. Recognition of GV Customers

During formulation, ground validation is fully cognizant of its customers in the science community. To this end, the GV program is soliciting the needs, desires, and advice of these researchers. The specific customers of the GV effort are: (1) algorithm developers, (2) data assimilation scientists, (3) climatologists, and (4) ground validation scientists. Algorithm developers are interested in improving the accuracy of their satellite retrievals and with validating and refining the underpinning assumptions and models. Data assimilation scientists rely upon variational methods when incorporating precipitation data into their models and forecasts. Assimilation requires a method to weight the observational data in proportion to the forecast weighting and forward model weighting. Error characterization, in the form of error covariances, is essential information for providing the appropriate weighting to the observational data. Climatologists are interested in long-term trends and the separation of short-term 'noise' from meaningful signals. For climatologists, error characterization, in the form of systematic error removal and uncertainty estimates, provides credibility to the satellite data. The final customers, ground validation scientists, are interested in improving the craft of GV and in the fundamental precipitation research that is essential to the effort.

III. GROUND VALIDATION APPROACH

A. Supersites

For the purposes of Ground Validation, GPM has divided the world into four distinct regions to be addressed by separate validation sites and focused programs. These regions are: (1) Tropical Open Ocean, (2) Mid-Latitude Continental, (3) Tropical Continental, and (4) Mid-Latitude Open Ocean. It is understood that this is an approximate, but necessary, division of the globe. Despite the deficiencies of this delineation, these regions are intended to represent distinct climates and geographic regimes.

Supersites are defined by their responsibility to provide operational error characterization to the satellite retrievals. It is expected that the each supersite will address the error characterization for its respective region. For example, a supersite in the tropical Pacific Ocean will be responsible for providing uncertainties and systematic error estimates to the satellite products generated over the global tropical oceans. Figure 1 is a representation of the data flow of a supersite with the other GPM program elements. In this scenario, the supersite will deliver error characterization in the form of "expansion rules" and "bias reports" representing respectively, error covariance and systematic error.

The instrumentation for the supersites is a matter of ongoing requirements development. Although some commonality of instruments between supersites is expected, the choice of instrumentation will differ, recognizing the unique nature of each site. The data processing and analysis facility of the supersite is not necessarily co-located with the supersite instrumentation.

B. NASA Commitment

With contributions from partner organizations, NASA will design, equip, maintain, and manage two supersites. In particular, it is expected that NASA will provide a Tropical Open Ocean Supersite at Kwajalein Atoll in the Republic of the Marshall Islands in the western Pacific Ocean [2]. The Kwajalein site is favorable for at least three reasons: (1) ample precipitation, (2) developed infrastructure, and (3) heritage as a Tropical Rainfall Measurement Mission (TRMM) validation site. The Department of Defense, and in particular the United States Army, manages facilities within the Kwajalein Atoll for its ballistic missile test program. Common approaches to meet the needs of GPM and those of the Army will be explored to the fullest extent.

The second NASA supersite is intended for north-central Oklahoma / south-central Kansas and co-located with the facilities of the U.S. Department of Energy's (DoE) Atmospheric Radiation Measurement (ARM) Program Southern Great Plains (SGP) Clouds and Radiation Testbed (CART) site. The SGP site has numerous advantages including: (1) varied precipitation, storm types, and seasons, (2) developed infrastructure, and (3) complementary research objectives to the ARM program.

In addition to the two supersites, NASA will provide a regional rain gauge network. Typically, a regional rain gauge network will cover an area several hundred kilometers on a side with consistent gauge spacing; they are sometimes referred to as 'mesonets'. Select locations with higher gauge densities within the network may be desired. The NASA gauge network is intended for central Florida in conjunction with NASA Kennedy Space Center and several Florida Water Management Districts. NASA has considerable experience with this network since it is currently employed for TRMM GV activities.

C. International Participation

By necessity of its global nature, GPM ground validation relies upon the participation of international partners. The two NASA supersites address only two of the four validation regions; global error characterization relies upon additional sites and research beyond that of the NASA contribution. In terms of resources, this participation spans the gamut from select ground instrumentation, to rain gauge networks, to complete supersites. It is anticipated that the Communications Research Laboratory of Japan will develop a supersite in Okinawa and will employ a bistatic polarimetric radar among the instrumentation [3]. Other international partnerships are expected to mature as GPM develops.

D. Interfaces and Data Flow

The Ground Validation system will interact routinely with the Precipitation Processing System (PPS) of GPM as illustrated in Figure 1. Expansion rules are envisioned as a combined algorithm and rule base enabling the PPS to calculate the error covariances. Each supersite will deliver its own set of expansion rules for their respective region of the globe. The dotted line associated with expansion rules indicates that this is not a regularly scheduled transfer but rather an updated transfer on a version improvement basis. Bias reports are envisioned for delivery on a regular basis on a timescale appropriate to the seasonal precipitation frequency at each of the supersites. The techniques required for bias report generation are expected to involve comparisons between the ground perspective and satellite overpass data. This is illustrated in Figure 1 by the flow of overpass subset data from the PPS to the supersite processing and analysis facility.

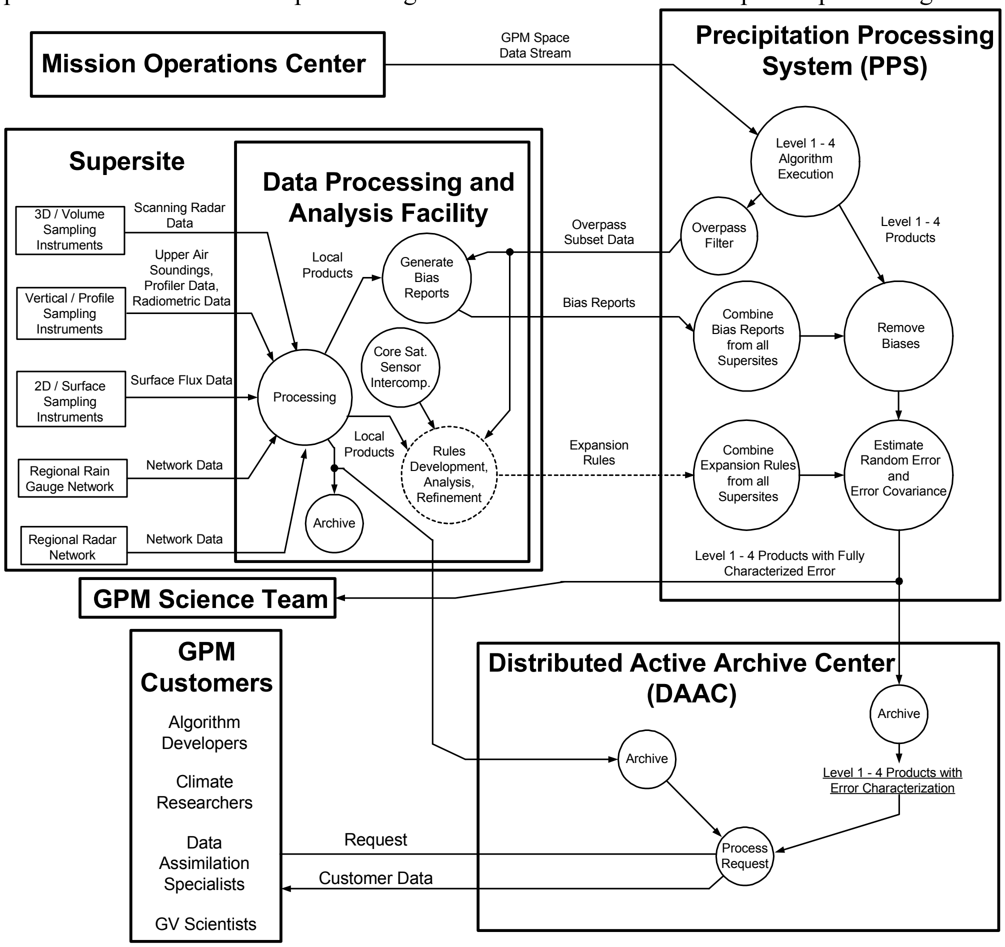

Figure 1. Error characterization production and flow for the ground validation supersite.

E. Focused Measurement Approach

In addition to the operational activities of the supersites, the GV program will conduct field campaigns and work devoted to focused objectives. For example, focused activities will address geographic and climatological regions of the globe where supersites may not be feasible. In particular, the mid-latitude oceanic region may be best addressed by field campaigns and focused work. The focused approach will not deliver or be responsive directly to the PPS in an operational sense as are the supersites. The focused activities, although addressing the three objectives of GV, will provide their results in a less structured manner.

REFERENCES

[1] S.W. Bidwell, S. Yuter, W.J. Adams, D.F. Flaming, and E.A. Smith, "Plans for Global Precipitation Measurement Ground Validation," IGARSS 2002, Toronto, Canada, July 2002.

[2] W. Adkins, and S. Yuter, "Potential Tropical Open Ocean Precipitation Validation Sites", GPM Report 5, NASA/Goddard Space Flight Center, Report Series Editors Eric A. Smith & W. James Adams, October 2001.

[3] S. Satoh, H. Hanado, K. Nakagawa, T. Adachi, and T. Iguchi, "COBRA (CRL Okinawa Bistatic Polarimetric Radar) as a Main Sensor of a Possible GPM Super Site in Okinawa," Second GPM Planning Workshop, Tokyo, Japan, May 20 – 22, 2002.